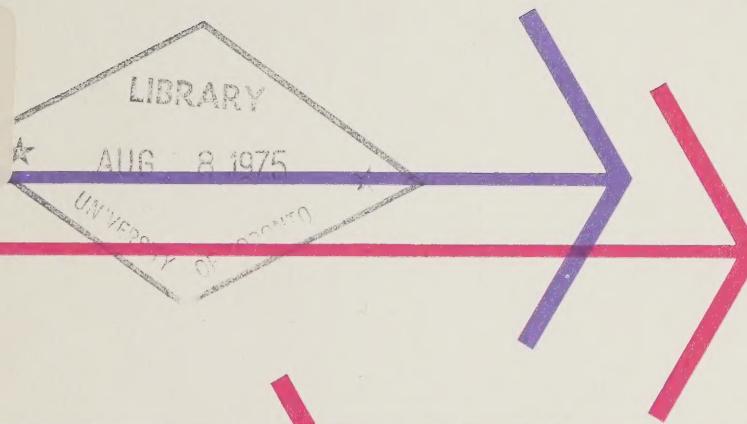


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# The official plan • network diagrams

MINISTRY OF TREASURY, ECONOMICS AND INTERGOVERNMENTAL AFFAIRS

The Honourable W. Darcy McKeough, *Minister*

A. Rendall Dick, *Deputy Minister*

G. Keith Bain, *Director*  
Local Planning Policy Branch

## PREFACE

Techniques to help planners devise and direct large scale projects have developed rapidly in the last decade and are gradually being applied in planning practice. Little practical experience is evident throughout this province although there are a few notable exceptions. The scale and complexity of planning studies provide ample reasons for a much greater use of available methods. This manual examines the application of one such technique — network diagramming — and its usefulness in the preparation of official plans in Ontario.

The manual is intended to serve several purposes. It can be viewed as a device to acquaint municipal planning agencies with the techniques and advantages of network analysis. It can serve as an introduction to a whole range of methods by which the benefits of improved planning, scheduling and control may be obtained. Most importantly, perhaps, it provides planning agencies with a new tool for formulating and justifying the content of work programs leading to the adoption of official plans.

Ample illustrations have been included to assist in an understanding of the ideas presented in the text. Central to the presentation are three case studies of specific official plan activity in three Ontario municipalities representing differing degrees of urbanization and staff availability.

An annotated bibliography of publications is included as an appendix to assist those who wish to explore the subject further. Under certain circumstances, material in the Library of the Department of Municipal Affairs might be available on an inter-library loan basis.

The manual was prepared by a private consultant, Mr. Robert W. McCabe, M.T.P.I.C., under a research grant made by the Community Planning Branch of the Department of Municipal Affairs. Mr. E. Searle of the Official Plans Section was of great assistance within the Community Planning Branch. His intimate knowledge of the procedure for obtaining approval of an official plan once it has been adopted by the council of a municipality and of the case study municipalities was critical to the successful completion of the program. We are also grateful to Mr. Kurt Mumm, Planning Officer, City of Kingston, Mr. Paul H. Pirie, Planning Director, J. M. Tomlinson and Associates, and Mr. William F. H. McAdams, Planning Director, Central Ontario Joint Planning Board, for their patience and for their practical guidance through the maze of detail inherent in official plan formulation.

July 1968

M. H. SINCLAIR  
Head  
Research & Special Studies  
Community Planning Branch

## PREFACE TO SECOND PRINTING

Readers familiar with the organization of government in Ontario will recognize that the names of certain planning agencies have changed since this publication was first produced in 1968. However, the methodology described here for the application of network diagrams to the planning process is still relevant and, because of its continuing popularity, the publication has been reprinted without alteration.

March 1975

M. H. SINCLAIR  
Manager  
Special Studies Section  
Local Planning Policy Branch

Local Planning Policy Branch,  
Ministry of Treasury, Economics  
and Intergovernmental Affairs,  
Queen's Park, Toronto, Ontario

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## I. INTRODUCTION

Urban and regional planning typically involves complex work programs extending over lengthy periods of time. Some programs, in fact, never actually come to an end but are on-going. They are usually described in terms of a number of steps or projects which, when completed, mark the end of a program, or a major phase in it. Each step is normally interrelated to the others and must be performed in sequence, either because of the logic of the planning process itself or because of the requirements of The Planning Act in Ontario.

Simplistic techniques for the planning, scheduling and control of such lengthy and complex tasks have been available for many years. Usually these have been borrowed from industrial engineering applications. More recently a number of advanced methods have been developed. The principal concern of these methods is to determine how best to schedule all jobs in a project to meet a target date at minimum cost, and to demonstrate which jobs are critical in their effect on total project time. The use of a computer would depend primarily on the scale of the projects involved.

Two variants are most commonly referred to, PERT (Periodic Evaluation and Review Technique) and CPM (Critical Path Method). PERT was developed in 1957 by the Special Projects Office of the U.S. Navy as a means of shortening by two years the time required to bring the Polaris Missile System into operation. CPM was developed concurrently by Dupont de Nemours and Sperry-Rand to improve the planning, scheduling and coordination of the downtime for maintenance in the former's neoprene process. Network diagrams form the basis upon which both PERT and CPM have developed.

*PERT* involves the periodic evaluation and review of the progress being made in each job within a major project. At certain stages, known as milestones, a number of key elements may have to come together to allow the next phase of the program to be started on time. The early identification of problem areas, and the recognition of where and when resources must be reallocated to keep a project on schedule, are of obvious importance to the project director.

*CPM* involves a recognition that during the progress of a project, one specific sequence of events may be critical to keeping the whole project on schedule, both in terms of time and of cost.

The development of sophisticated techniques for the planning, scheduling and control of complex programs has a number of important implications for the urban and regional planner.

1. They provide a means of plotting out in advance how a program is to be accomplished with accuracy and realism.
2. They detail the steps involved, the sequence in which each can best be performed, and the interdependencies that must be recognized.
3. They allow an evaluation to be made, in advance, of the time and costs involved to complete the program under alternative allocations of resources and completion dates.
4. They indicate how a variety of professions, departments and agencies may be coordinated when the efforts of each depend upon and influence those of the others.
5. They focus attention on the small subset of critical jobs along the “bottleneck” path through the program and allow a study of the effects of crash programs on time/cost estimates, on other critical jobs, and on completion dates.
6. They produce useful information all the way through the project from initial planning to final presentation so that control may be effective, as well as providing a permanent record of how the project was completed.
7. They may be required of consultants when making a submission to insure that a complete job will be done and that fees can be related to specific accomplishments.

Perhaps the most significant implication for the planner is that the use of network diagrams provides an added tool by which the planner may illustrate to planning board members or others not fully familiar with all the methods of planning:

- a) What adoption of a particular program involves in the way of research and special studies.
- b) What relationships exist between a planning program and other studies, such as traffic studies, sewer studies, etc.
- c) What the consequences will be if certain steps are omitted or if specific studies are deleted.

The effect of decisions in these important areas on the quality of the resulting plans is obvious.

This manual does not provide ready-made schedules for all planning activities in every municipality or planning agency. It demonstrates by actual examples what the schedules for the preparation of an official plan under The Planning Act in Ontario look like in network diagram form. It outlines how an agency may go about preparing a network diagram for any of its own activities and how the diagram may be used to improve performance.

The preparation of an official plan is usually a unique occurrence. The program adopted for its accomplishment will vary considerably depending upon a variety of factors. Some planning offices may have large professional staffs, some may depend on outside assistance, some may be single independent agencies, some may form part of a larger joint planning area, and so on. All can chart their planning activities through network diagrams and obtain the benefits of improved planning, scheduling and control.

The manual is organized so that those already familiar with charting and flow diagrams can move directly into network diagramming using the outlines and illustrations provided. For those who may wish to pursue the topic, even more advanced methods of mathematical computation are included. For those to whom the concepts of PERT/CPM are rather new, a brief background is provided in the next section.

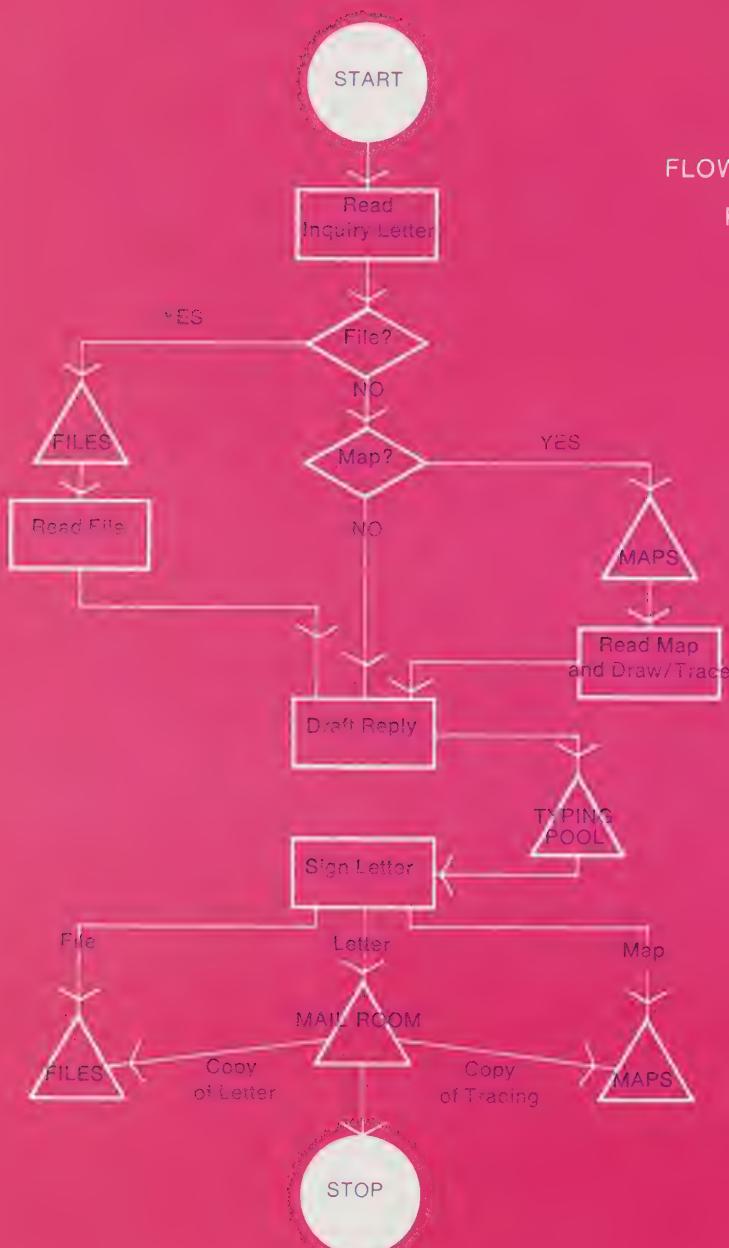


Figure 1.  
FLOW CHART OF A CLERICAL ROUTINE  
Flow Chart of Mail Answering Routine  
in a Planning Office



## **II. PLANNING, SCHEDULING AND CONTROL**

The evolution of the current family of network-based project management systems is of interest because it reveals, in part, the steps involved in going from a decision to carry out a major project to a series of detailed network diagrams. Each step carries the program plan to a greater level of detail and ends with complete information on how the project is to be carried to a successful conclusion within the allotted time and resources.

The charting of work flows has been a common practice in most industries for many years. The procedure for diagramming such flows in manufacturing, clerical activities and in data processing is highly developed. Operating efficiency is improved by a study of the flow charts to reduce the number of operations, rationalize their sequencing, reduce the time taken and, as a result, reduce costs.

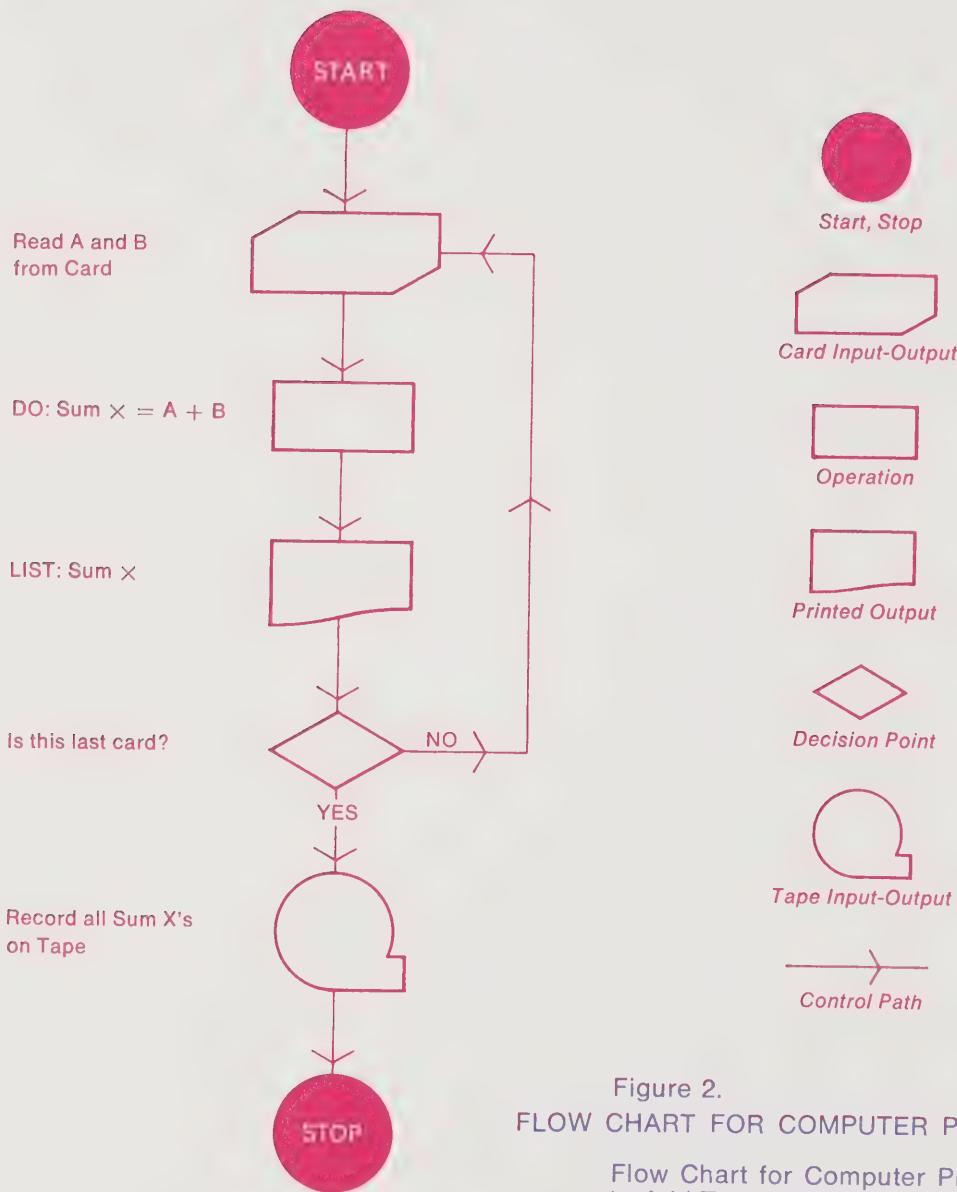


Figure 2.  
FLOW CHART FOR COMPUTER PROCESSING

Flow Chart for Computer Processing  
to Add Two Numbers, Print the Result  
and Store on Magnetic Tape

Figures 1 and 2 illustrate two of the customary applications. Figure 3 indicates in a manufacturing process how a master breakdown chart may be employed to determine the way in which a finished product may be exploded into its components at successive stages of manufacture and assembly. The examples demonstrate how the flow of work and materials may be studied in great detail by the use of common symbols and charting techniques.

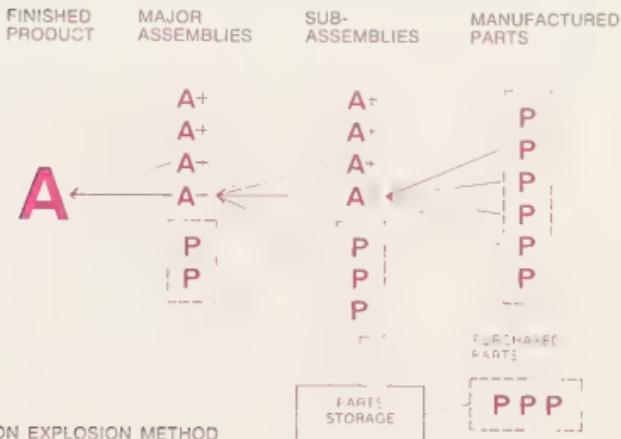


Figure 3 PRODUCTION EXPLOSION METHOD

*Master Breakdown Chart — Illustration of the use of "production explosion" method to determine how a finished product may be built up from major assemblies, sub-assemblies, and the manufacture or purchase of component parts in a manufacturing process.*

Source: L. P. Alford and J. R. Bangs. *Production Handbook*. Ronald Press, 1946

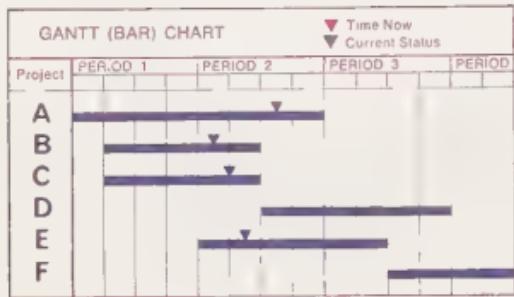
Similar techniques have been used to chart the planned progress of work through a complex series of steps to completion, to schedule the work and to control production. The Gantt Chart, developed in World War I by Henry L. Gantt, has been until recently the most commonly used scheduling and control form. It is from Gantt's bar charts that network analysis has sprung. Figure 4 shows graphically how both PERT and CPM arrived at a common use of network diagrams to serve their own purposes.

A brief look at the illustrations referred to so far has no doubt confirmed that network diagramming has a language of its own. The most commonly used terms are defined in Appendix A and variations in usage between PERT and CPM are included in Appendix B which compares both methods. There are only a few terms which are needed for an initial understanding of network diagrams.

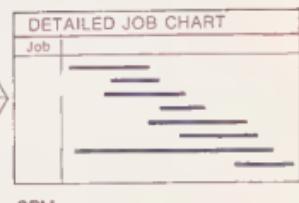
Figure 4.  
THE HISTORICAL EVOLUTION OF THE NETWORK DIAGRAM

SOURCE: *Introduction to Network Planning*. Department of City Planning, Pittsburgh, 1963.

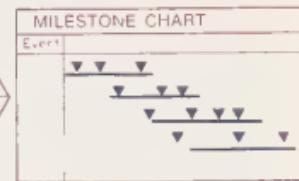
PHASE I



PHASE II

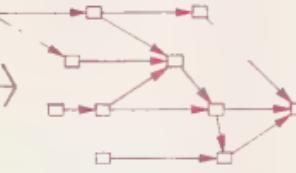


CPM



PERT

PHASE III

CPM ARROW DIAGRAM  
(ACTIVITY ORIENTED)PERT NETWORK  
(EVENT ORIENTED)

PHASE IV



NETWORK DIAGRAM

○ Event  
→ Activity  
— Critical Path

Figure 4.  
THE HISTORICAL EVOLUTION OF THE NETWORK DIAGRAM

SOURCE: *Introduction to Network Planning*. Department of City Planning,  
Pittsburgh, 1963

There are certain milestones or significant events that will be encountered in preparing an official plan. These milestones can be used as checkpoints to keep track of the project if one wishes to control the process at each stage. An event, then, is the start or completion of a significant task but not the actual performance of the task itself. Events do not consume time or resources but merely mark a recognizable node in the project. Events follow each other in a logical sequence from the start of the project to the finish, or *end event*. In a network diagram the order of events is indicated by a series of circles (the events) and arrows (the sequence).

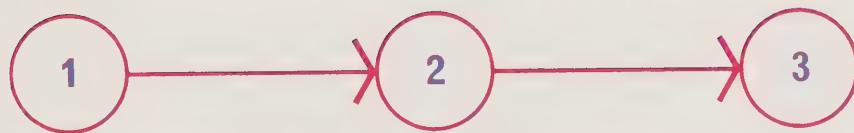


Figure 5. EVENTS AND ACTIVITIES IN SEQUENCE

If an event marks a milestone achieved, the actual performance of the work which must be accomplished before the event is called an *activity*. Activities link network events. Since activities normally involve work on someone's part they consume time and require manpower, space or other resources.

*Successor events* are events that immediately follow one another without intervening events. *Predecessor events* are those that come immediately before an event without intervening events.

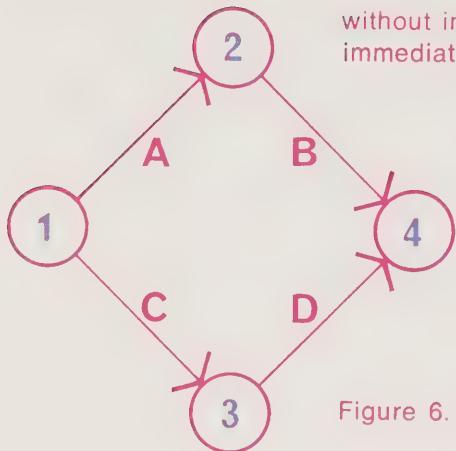


Figure 6. SUCCESSOR AND PREDECESSOR EVENTS

In Figure 6 events are numbered 1 to 4. Activities are designated A to D. Events 2 and 3 are successor events to 1 and predecessor events to 4. Activities A and C cannot be commenced until Event 1 has occurred. Event 4 cannot be reached until Activities B and D are completed. Activities B and D are *constraints* on Event 4. Event 1 is a constraint on Activities A and C.

Not all activities have durations associated with them. In Figure 6 Activity B may require no manpower input. It may be placed on the diagram as a *dummy activity* with *zero-time* to indicate that Event 2 must precede Event 4. In some instances such activities are indicated by broken arrows or dotted lines.

Some events are referred to as *interface events*. An interface occurs when there is transfer of responsibility to/from another network or to/from an outside agency. In Figure 6 Activity C might imply the sending of a preliminary drawing to another department for comments. Activity D would then likely acknowledge that a reply would be necessary before Event 4 can be considered accomplished.

In a complicated network there may be dozens of pathways through the network which may be followed in logical sequence from the start to the finish of the project. By assigning to all the activities an estimate of the time required to complete each activity (*duration*), it is possible to determine which of the pathways will take the longest time or consume the most work-days.

Times are normally stated in working days, weeks or months. This pathway is known as the *critical path*. It is only along this pathway that means can be found to shorten the start-to-finish time overall. A reduction of time consumption along any other path may reduce costs but will not bring the completion date forward. If a reduction is possible along the critical path, it may no longer be the critical path. Another route may then become critical.

A common strategem, when all else fails, is to introduce a *crash program* to speed up the completion of all activities at added costs in manpower, overtime or fatigue. To do so is normally wasteful and unnecessary because it is only if activities along the critical path are crashed that a speed-up can be achieved. Observations indicate that in a typical program only about 10 percent of the jobs are critical in this respect.

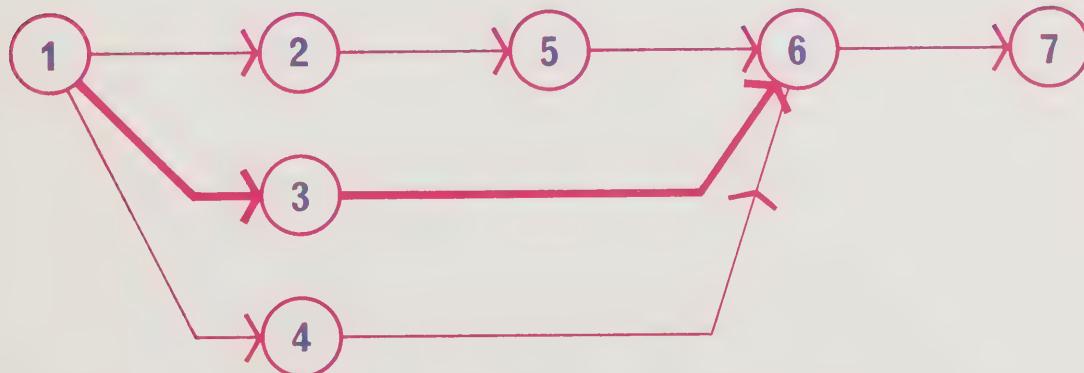
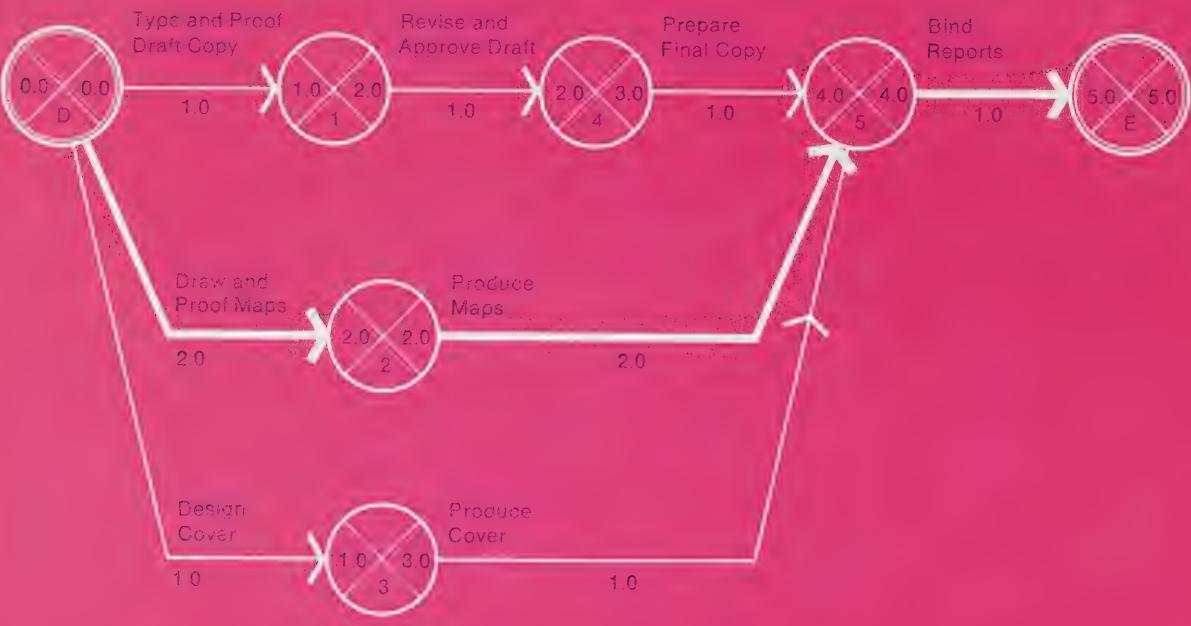


Figure 7. THE CRITICAL PATH

Figure 8. DETAILED NETWORK DIAGRAM



When all the duration times have been totalled for each path and the critical path determined, the calendar date for completion of the program can be calculated. This is known as the *expected date*. Once an expected date is known, the schedule can then be examined, *scheduled times* allocated to each activity and *scheduled completion dates* set for the completion of each activity or the occurrence of each event. An examination of the network may be made to reallocate resources or to adjust the time allowance by eliminating *slack* if the expected date does not meet the *target date*.

Once a program is underway, scheduled completion dates may be watched and *start and finish dates* checked regularly to ensure that no event occurs past a date which will create an expected delay in the completion of the project (Figure 8). More detailed control of projects is provided through the techniques of Periodic Evaluation and Review (PERT). However, these are beyond the scope of this manual, and are probably unnecessary in all but the most critical planning projects — during the construction phases of urban renewal schemes, for example. Detailed information sources on this aspect of PERT/CPM will be found in Appendix C, Annotated Bibliography.

### **III. METHODOLOGY**

The preparation of a network diagram flows logically from the process of project planning and scheduling. It is not an easy job. A number of basic tools are available to aid the planning director and those who supervise the work of others on his behalf. A brief outline is given here. A little imagination can indicate how further refinements can be devised.

## 1. WORK BREAKDOWN STRUCTURE

The first step in approaching a major program is to divide or break the program into a number of constituent projects, each of which must be completed before the whole program can be considered finished. This type of breakdown may be considered analogous to the work explosion method shown in Figure 3.

In the preparation of an official plan the whole program has been typically recorded as a series of projects. For example, the program may be viewed as divided into five constituent projects:

- A. Survey
- B. Analysis
- C. Plan Formulation
- D. Evaluation of Alternatives
- E. Preparation of Final Plan

This is obviously an oversimplification of the process of planning but it represents a logical first step in exploding a program into a set of operable steps. These same steps are illustrated in a slightly more detailed manner farther on in Figure 13.

Two aspects of work breakdowns may be noted at this stage:

- a) End objectives must be carefully defined in the beginning.
- b) Breakdowns should produce a series of accomplishable jobs each of which may add the element of satisfaction that is to be derived from a task completed.

PROJECT	PERIOD 1	PERIOD 2	PERIOD 3	PERIOD 4	PERIOD 5	PERIOD 6
A	□	○	□			
B		□	○	□		
C			□	○	□	
D				○	○	□
E				□	○	
F					□	
G					□	○

TASK	PERIOD 3	PERIOD 4	PERIOD 5	PERIOD 6		
1	□	□				
2	□	○	□			
3		○	□			
4		□	○	□		

TASK	DEPT. A		DEPT. B		DEPT. C			DEPT. D		
	Sec. 1	Sec. 2	Sec. 1	Sec. 2	Sec. 1	Sec. 2	Sec. 3	Sec. 1	Sec. 2	Sec. 3
1	X	X								X
2		X	X							X
3	X								X	X
4					X	X	X			X

## 2. MASTER PHASING CHART

Figure 9. MASTER PHASING CHARTS AND TASK MATRIX  
see diagrams on page twenty-six

*top: MASTER PHASING CHART*

*middle: TASK PHASING CHART – PROJECT D*

*bottom: TASK MATRIX – PROJECT D*

Master phasing charts and a task matrix can be prepared once the constituent projects have been recognized. The phasing charts consist of an outline of the whole program over time. Simple illustrations are shown in Figure 9. It will be noted that the total program is phased into projects and that each project is phased as a series of tasks. Milestones and interfaces are shown in the phasing charts and carried down to the lowest level of detail.

Control of specific tasks can be accomplished by use of the master task matrix which shows how the work has been assigned. This matrix is also useful in the scheduling process when a review is made of resources allocated in relation to slack. The master task matrix adds a further dimension to network diagramming by providing a program which will have meaning for the people who are to perform the tasks.

NETWORK LIST				
DESCRIPTION	Number	RESPONSIBLE		Approved by
		Section	Prepared by	

EVENT LIST					
Identif'n No.	DESCRIPTION	TYPE M : Milestone i : interface	RESPONSIBLE		Schedule Date
			Organization	Individual	

ACTIVITY LIST			
Serial No.	DESCRIPTION	Immediate Predecessor's	Duration Time

### 3. NETWORK AND ACTIVITY LISTS

The use of network, event and activity lists is not essential to network diagramming. Yet, as additional planning aids they ensure that nothing important is omitted from the network and they speed up the process. The information contained in each is shown in Figures 10, 11 and 12, on page twenty-eight.

Figure 10 (top): NETWORK LIST

Figure 11 (middle): EVENT LIST

Figure 12 (bottom): ACTIVITY LIST

The level of detail to be depicted is optional and depends entirely on the degree of control desired and the familiarity of staffs with the work involved. A greater level of detail will help ensure that costs and target dates are met more exactly. Where a general control is considered sufficient, outline networks may be acceptable. A normal approach would be to create a hierarchy of networks in which parts of a higher order network are shown in greater detail at the next level of networks. This scheme will allow the director to control the overall program at a gross level, still ensuring that detailed control is applied in specific areas of work supervision and responsibility.

The event list is of great importance in identifying areas of uncertainty, particularly where an event is of the interface type. Both the event and the activity lists are working lists designed to eliminate continual revisions as the network is developed and to prove out the logic of the sequencing envisaged.

#### 4. PREPARING THE NETWORK DIAGRAM

The detailed preparation of a network diagram can be carried out in two ways. The network can be plotted by starting at the beginning and proceeding forward chronologically. Alternatively, the network can be plotted by starting with the *deliverable end product* and working backwards. Either method produces valid networks. Planning back from the end objective seems to work better. In either case the resulting network should read sequentially from left to right.

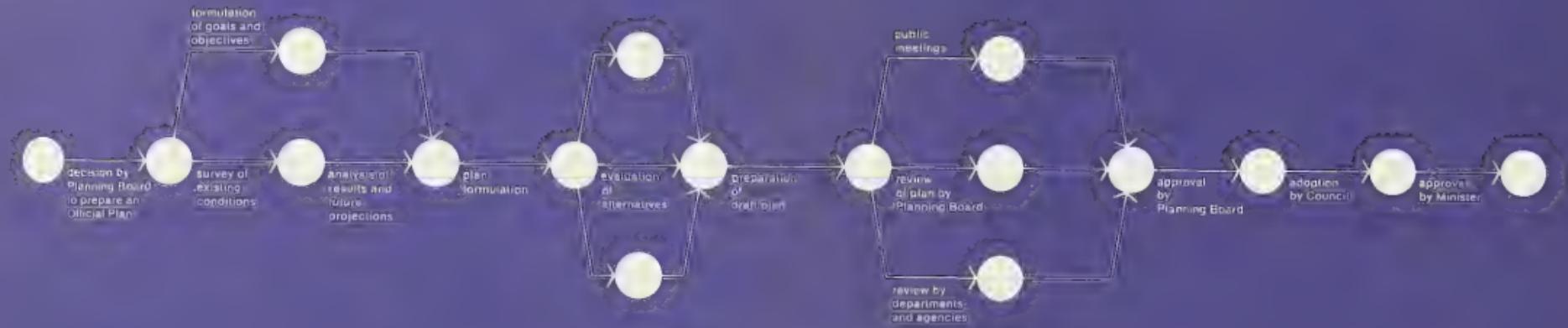


Figure 13.

OUTLINE NETWORK DIAGRAM FOR PREPARATION OF AN OFFICIAL PLAN



## OUTLINE NETWORK DIAGRAM FOR PREPARATION OF AN OFFICIAL PLAN

See under

Figure 13.

A number of general "do's" and "don'ts" may be noted.

- a) *DON'T* use a calendar scale at the beginning. Concentrate on the sequencing of events from the right to the left, i.e., from the end to the beginning.
- b) *DO* pay special attention to interface events, such as time spent awaiting decisions or comments from outside sources
- c) *DO* watch for loops. The looping back of activities in time may appear as a reasonable procedure, since this is often what appears to happen. However, the use of backward, or iterative loops can cause difficulties when it comes to assigning expected start and finish times for activities. Where calculations are to be made by hand in a small network, difficulties can be overcome. In more complex networks where computers must be used, activities which go back in time confuse the procedure and should be avoided
- d) *DO* draw networks in draft form. The ease with which programs may be analyzed, reviewed, revised or rescheduled is the essential purpose of preparing the diagram in the first place. It is a tool and not an end in itself. A large blackboard is a help.
- e) *DO* draw final networks in a form from which they can be readily reproduced. Network diagrams are information and everyone involved should have a copy
- f) *DON'T* assume that the preparation of a network diagram is a task for the office "expert" alone. There must be full participation in the process at each stage and at each level. The "committee" approach may seem to be less expedient, but will prove to be more reliable in the long run

## IV. MATHEMATICAL FORMULATION

### DETERMINING THE CRITICAL PATH

To simplify the calculations involved in determining the critical path through a network it is necessary to adopt a few standard notations. In the definitions given in Appendix A it is recognized that for each activity there is an *early start time* by which a job may begin if all its predecessors also start at their early start times. Similarly, there are *late start times*, *early finish times* and *late finish times*. These may be designated as:

ES — Early Start Time

LS — Late Start Time

EF — Early Finish Time

LF — Late Finish Time

te = Duration

If one refers to Figure 8 — the simple example of a network diagram for printing a report — it can be seen that the earliest and latest start times are inserted in segments of the event symbols. It is also possible to determine with little difficulty that the sequence of activities which includes the drawing and production of maps is the bottleneck route through the network. There is no slack between the duration times and the start and finish times.

A slightly more complicated example will now be introduced to indicate the way in which the critical path can be determined. In networks of up to 150 activities the calculations can be done conveniently manually. In larger networks computer programs take over. The example used here is intended for manual determination of the critical path. Appendix C contains ample illustrations of the use of

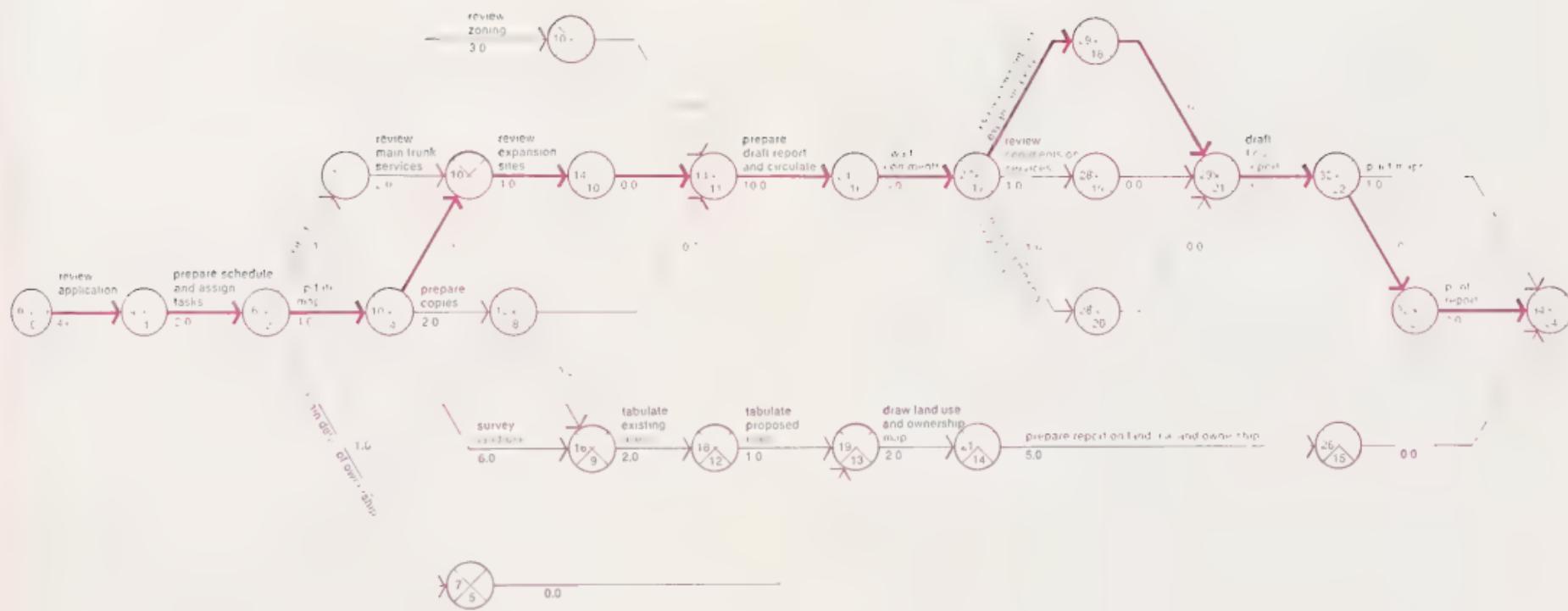
EXHIBIT I: EVENT LIST (see under)

EXHIBIT II: ACTIVITY LIST (see under)

EXHIBIT III: FINDING THE CRITICAL PATH (see under and opposite)







### Exhibit III FINDING THE CRITICAL PATH

### EXAMPLE – REVIEW OF A PLANNING PROPOSAL

A simple example has been devised to illustrate the methodology of determining a critical path and evaluating slack. In this case study it is assumed that an application for the development of a hypothetical site has been received by a planning agency and must be reviewed. The final result will be a set of presentation maps, a report on the application and a separate report on land use and ownership.

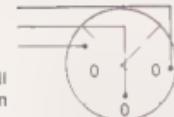
The logic and sequencing of the project may be questioned, and the whole process re-evaluated. If this is done a new event list, a new activity list and a new network diagram would have to be drawn. For purposes of illustration the proposed sequencing of events is used as presented.

An event list and an activity list have been prepared as Exhibits I and II. The resulting network diagram is shown as Exhibit III. If one traces the network from start to finish, it will be found that there are 27 unique paths through the network, with times ranging from a minimum of 14 days on path 0, 1, 2, 5, 13, 14, 15, 24 and a maximum of 34 days on path 0, 1, 2, 4, 7, 10, 11, 16, 17, 18, 21, 22, 23, 44.

This latter path is the *critical path*. It determines the overall time required to complete the review and indicates which jobs are critical. It reveals, for example, that there is no point in rushing the land-use survey because to do so will not result in completion of the project any sooner.

We now wish to calculate, for each event, the earliest start time (ES), and the late finish time (LF). This is accomplished using the network diagram.

Late Finish Time  
Event Number  
Early Start Time



1. In the starting event circle mark the start time. Normally this will be zero in a complete network. If a network is an expansion of an overall project network, the start time may have another value.

Figure 14 THE EVENT CIRCLE

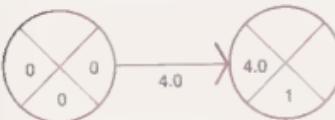


Figure 15  
CALCULATING THE EARLY START TIME

2. Move to the successor event and insert the ES time by adding in the duration time for the intervening activity.

3. If an event has more than one predecessor event, the ES value will be the highest ES value of all the predecessor events plus the longest duration time intervening.

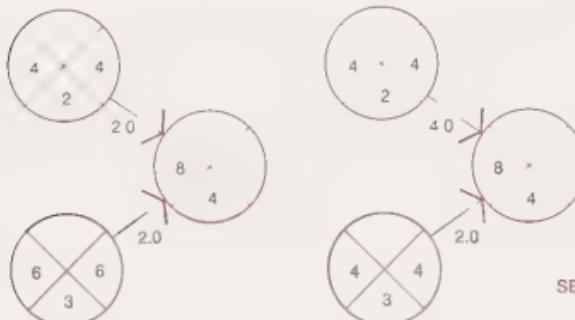


Figure 16.  
SELECTING THE ES VALUE

4. Continue until all ES values are recorded in the network.
5. Mark in the critical path route.
6. The ES value of the end event will indicate the shortest time in which the project can be completed. This equals the EF value or early finish date, i.e., the earliest date on which the project can be completed if all jobs on the critical path are started at the earliest start times.

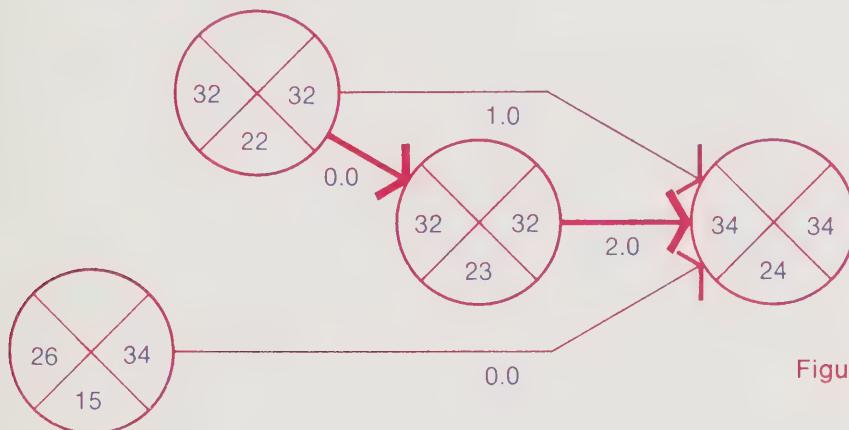


Figure 17. LATE FINISH TIMES

If we now reverse the process and trace back through the network from the end event, the LS values can be placed in the right-hand segment of each event circle. Along the critical path the ES and LS values will normally be the same. On all other paths, if there is only one critical path, the early start times will be less than the late finish times, indicating free slack time, i.e., the amount an activity can be delayed without delaying the start of any other activity.

In the example the earliest finish time is 34 days. If the *target date* for the completion of the project showed that there were 40 days available to do the work, it would be possible to review the schedule using late start and late finish dates. There would then be total slack of 6.0 days along the critical path.

Along pathways that are not critical the free slack on each job would increase and it would be possible to postpone the start of certain activities, to re-allocate resources to increase free slack along the critical path as a safeguard, or to smooth the work load in other projects by using the non-critical activities in this project as fill-in jobs.

It might even be decided to resequence the schedule of events completely and arrive at an alternative network diagram. In this case the calculations would have to be performed anew by hand. In small or medium size projects this would be no hardship. In the larger and more complex sequence of relationships involved in large scale urban and regional planning, a reasonable solution would require the use of a computer.

## V. EXAMPLES

The essential purpose of this manual is to provide planning agencies with a planning tool that will be a framework within which to develop their own network diagrams for the preparation of official plans. As a corollary, the preparation of a network can be considered an excellent opportunity to acquaint municipal authorities and agencies with the flow of work which is deemed essential and desirable in the preparation of any plan. It was pointed out in the introduction that network analysis is essentially a tool to:

1. Reduce projects to a set of milestones and tasks arranged in logical sequence.
2. Estimate the duration of each activity or job, drawing up a schedule in terms of time and manpower inputs, and finding which sequence of activities control the completion of the project within the time allowed.
3. Assist in the reallocation of resources (time, money or staff) to improve the schedule.

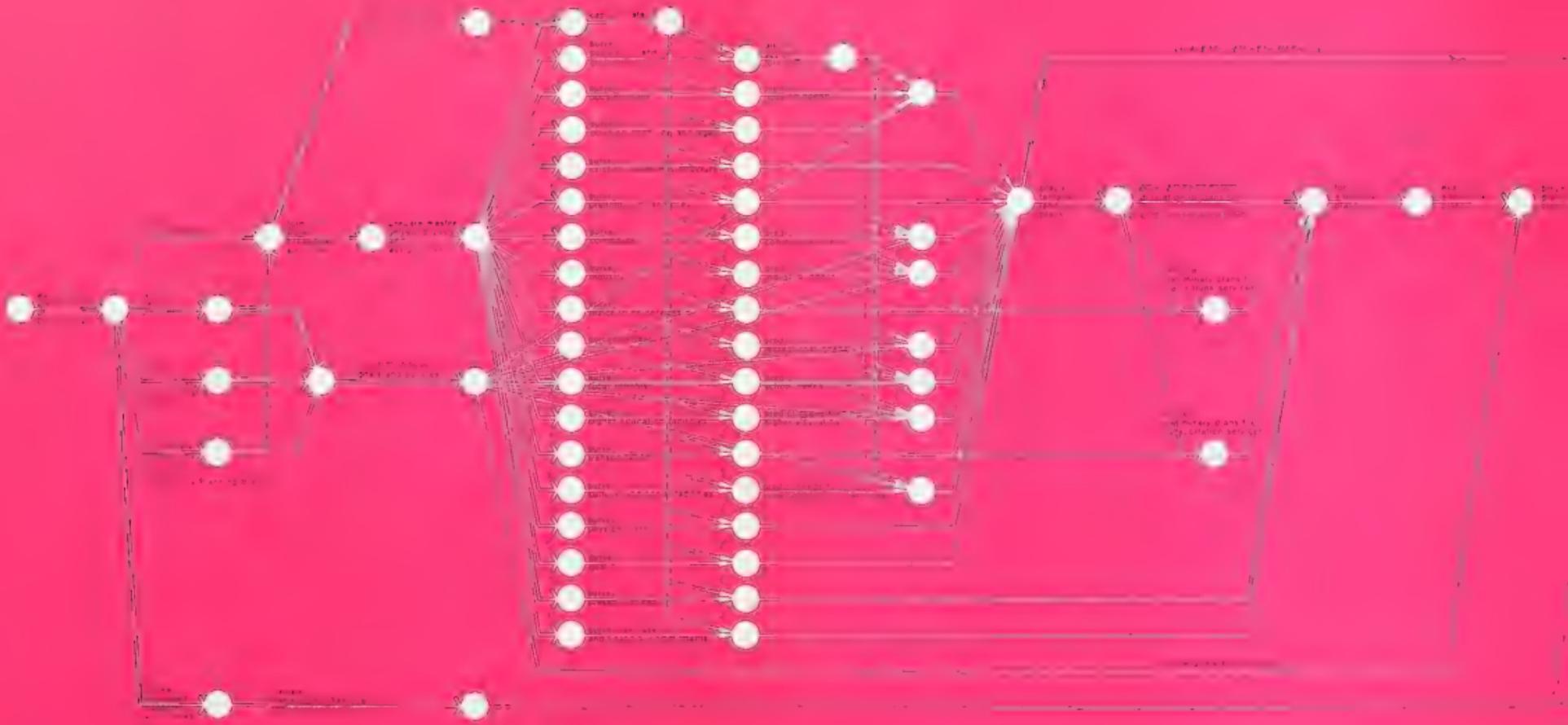
It was also pointed out that the preparation of a network diagram is a unique occurrence: no one network is applicable to all circumstances.

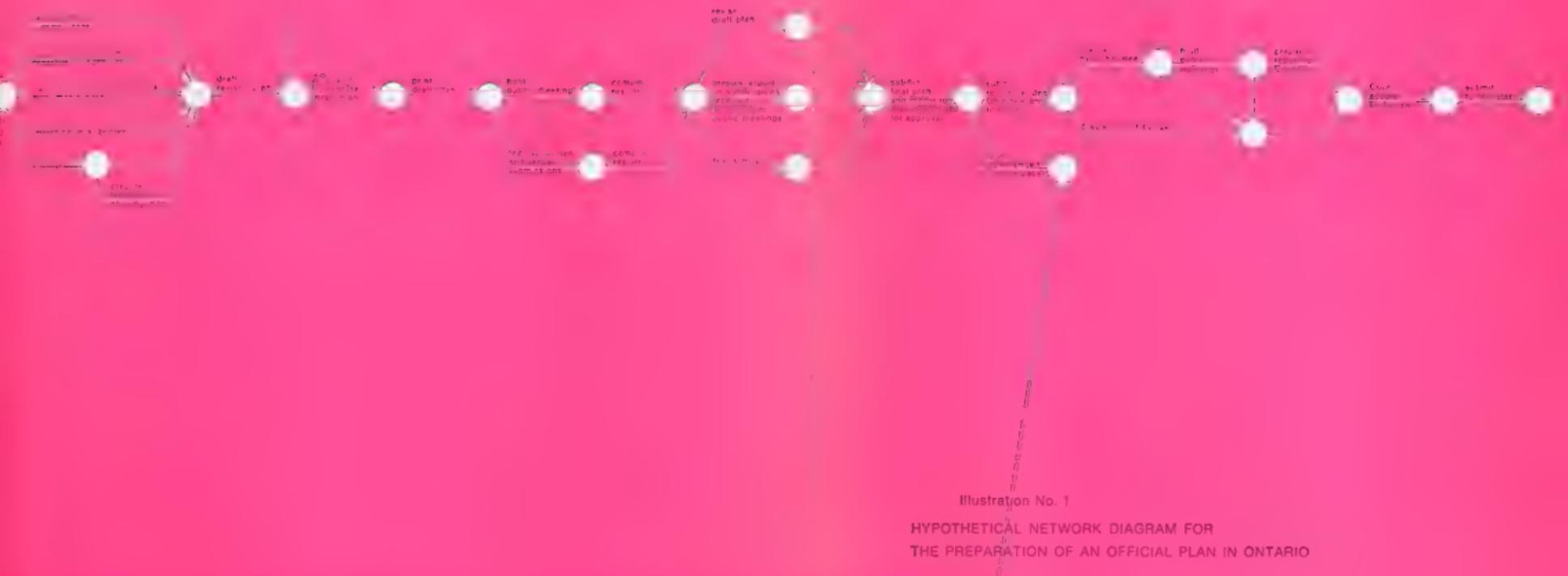
To illustrate these points lucidly, and to test the validity of the methodology, a number of network diagrams have been produced.

Illustration No. 1

35-102 NETWORK DIAGRAM FC  
THE PREPARATION OF AN OFFICIAL PLAN FOR THE CITY







1. *A Hypothetical Network Diagram for the Preparation of an Official Plan under The Planning Act in Ontario.* This diagram is not meant to be a "best" solution or the only solution to the problem of ensuring that all essential studies are completed in preparing an official plan. Rather it is an illustration of one approach which might be suitable in a hypothetical or theoretical sense. The network attempts to clarify the detail involved in the organization of a work program covering the essential steps set out in Figure 13. In this sense Figure 13 presents an outline network only and Illustration 1 a further elaboration of the outline. Presumably the network in Illustration 1 could be further refined into a series of even more detailed networks.



Illustration 2

## NETWORK DIAGRAM OF THE STEPS IN SECURING MINISTERIAL APPROVAL OF AN OFFICIAL PLAN

*2. A Network Diagram of the Steps in Securing Ministerial Approval of an Official Plan* illustrates the process by which review and approval of an official plan is obtained after it has been formally adopted by the council of a municipality and forwarded to the Minister. This is an actual representation of the flow of work through the Department of Municipal Affairs from receipt of the plan to notification to the municipality that their official plan has been approved.

The following three cases represent concrete examples in Ontario of the work inputs, sequences of events and final outputs in the form of actual case studies of planning activities in Ontario municipalities. Each of the municipalities chosen for study is typical of a class of planning situation encountered in Ontario: a joint planning area with considerable professional staff, a medium sized urban area with limited number of professional staff and a single independent planning area relying entirely on consultants.

In two instances official plan studies have resulted in the adoption and approval of an official plan. In the third the work program is well under way. The diagrams represent, in effect, actual experience as distinct from hypothetical situations or planning proposals. No value judgments are implied on the quality of the work being done.

Illustration 2.

NETWORK DIAGRAM OF THE STEPS IN SECURING  
MINISTERIAL APPROVAL OF AN OFFICIAL PLAN



Considerable difference will be noted in the diagrams for each of the case studies. It is important to realize that each of the work programs reflects a difference in the planning studies that had been undertaken prior to the decision to proceed with an official plan. Each municipality has been faced with similar yet distinctly different problems. As a consequence the emphasis and direction has been related directly to the local situation. For this reason the amount of study and analysis required prior to the plan formulation stage is not the same.

These differences provide ample illustration of the fact that the diagramming of a network is a unique occurrence in each municipality, although the general outline of the program is common to all official plan studies.

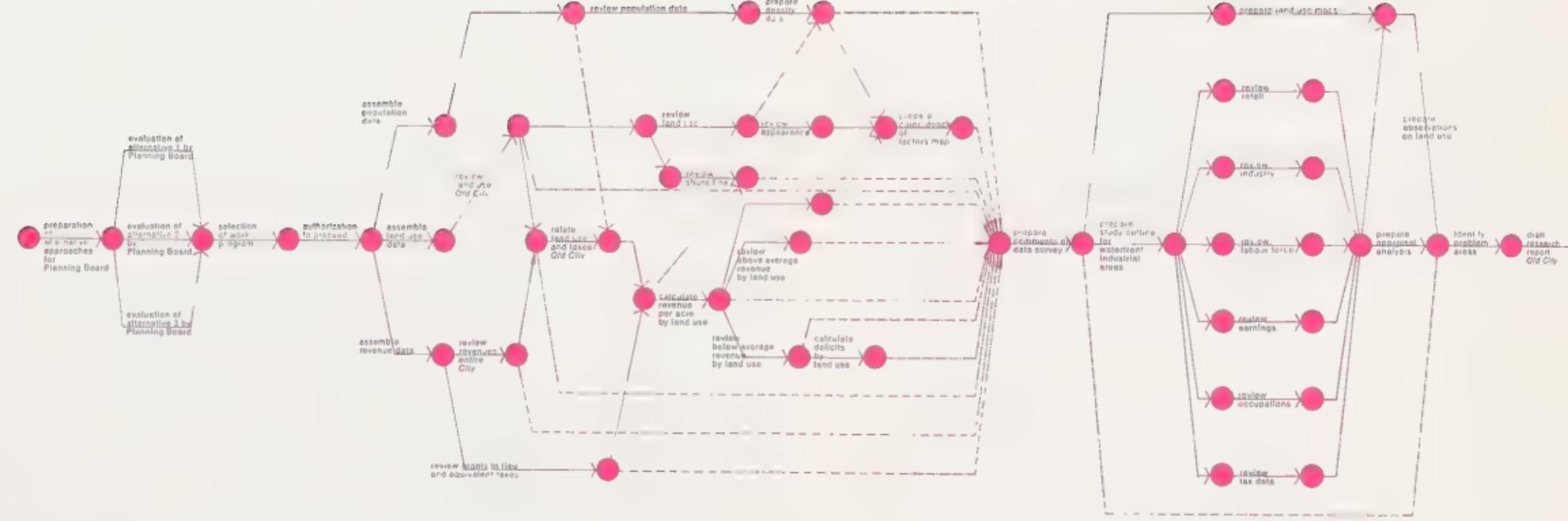
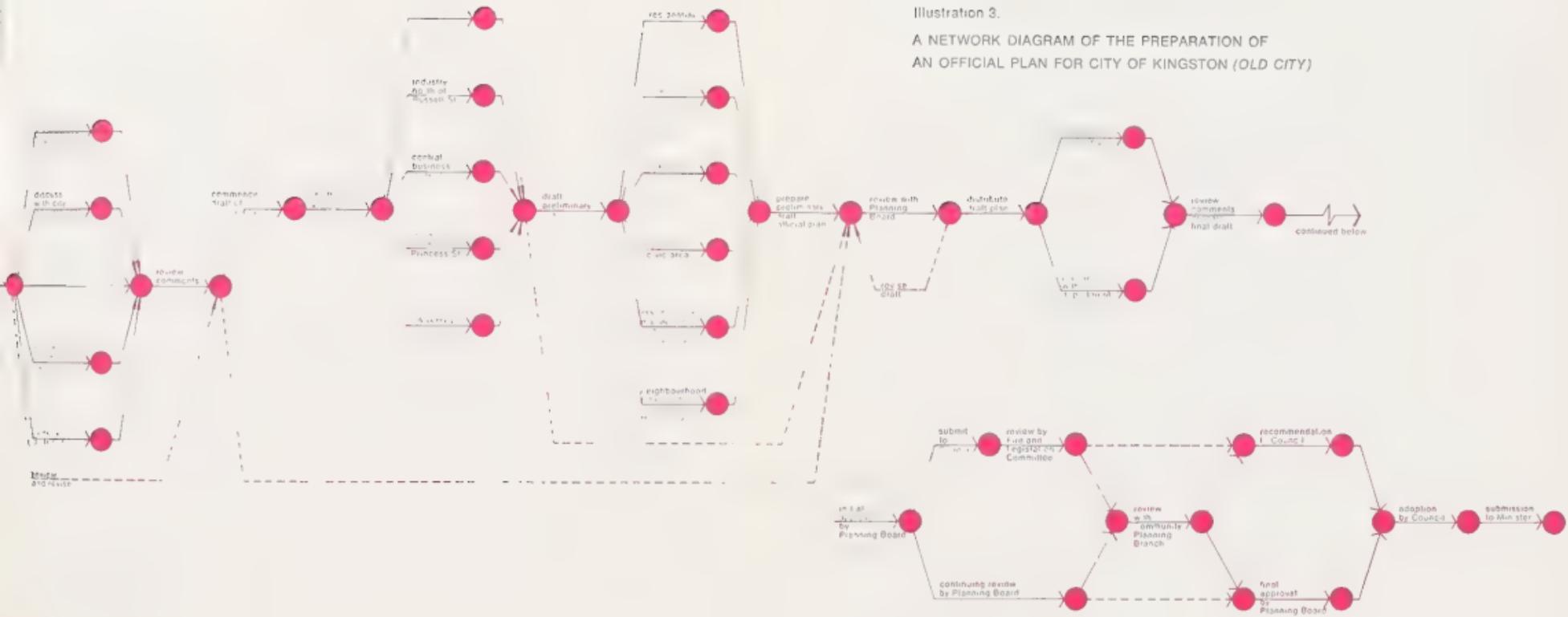


Illustration 3.

A NETWORK DIAGRAM OF THE PREPARATION OF AN OFFICIAL PLAN FOR CITY OF KINGSTON (OLD CITY)



3. *Network Diagram for the Preparation of an Official Plan for the City of Kingston (Old City).* The studies leading to the preparation of an official plan for Kingston commenced officially on February 13, 1964. The Stephenson-Muirhead Urban Renewal Study (1960) provided the basis for the decision to proceed and contributed much valuable background material of an appraisive nature.

The preparation of a plan for the whole city has proceeded in two steps. The first step was the preparation and adoption of a plan for the "Old City", i.e., that area of Kingston prior to the annexation of 5700 acres of land from Kingston Township in 1951. That plan was adopted by Council and subsequently approved by the Minister of Municipal Affairs in 1966. It is to this portion of the official plan that the network diagram presented here relates.

Work was commenced on a review of the official plan for the annexed area subsequent to the approval of the plan for the Old City. A detailed work program was devised and the project is currently underway. A network diagram has *not* been attempted to illustrate the work plans involved in this latter planning scheme.

Illustration 3.

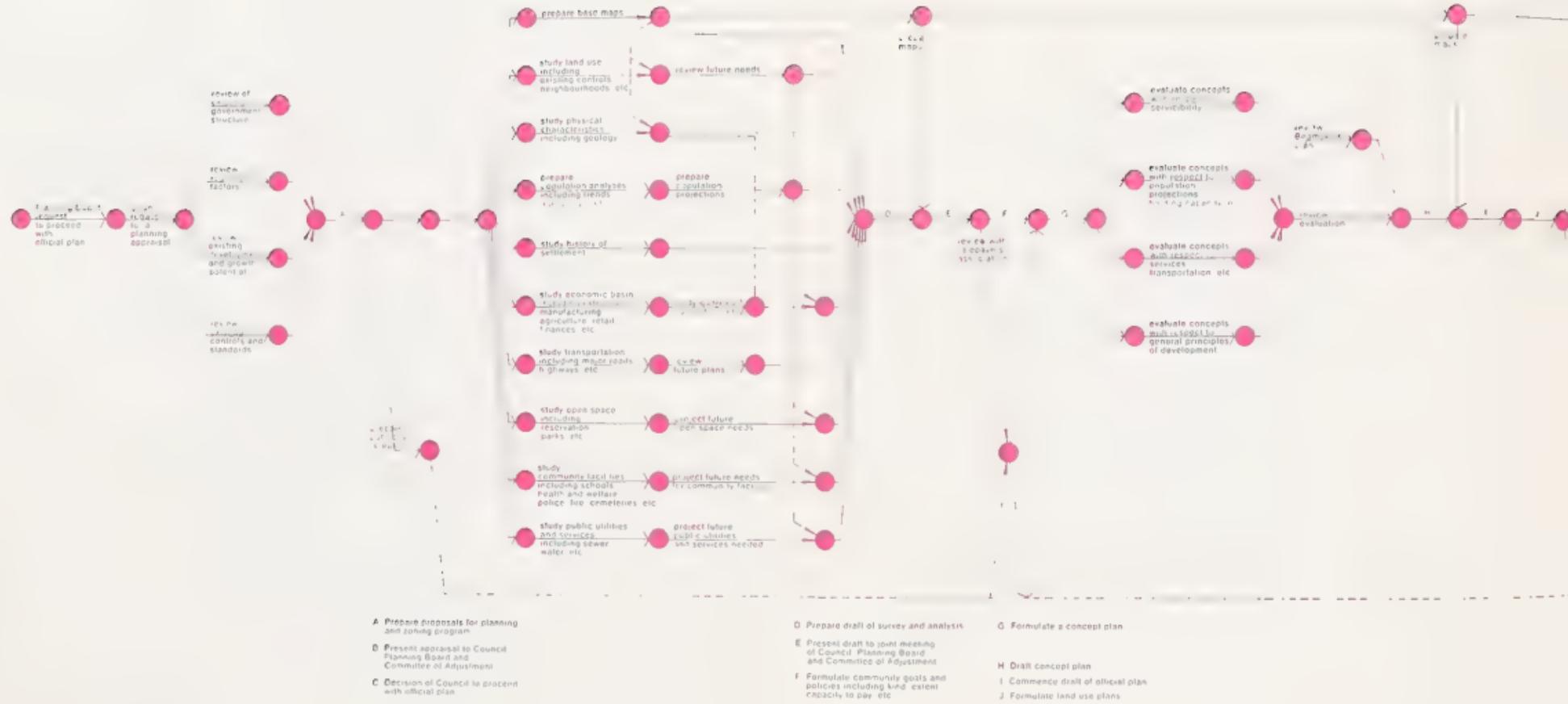
A NETWORK DIAGRAM OF THE PREPARATION OF  
AN OFFICIAL PLAN FOR CITY OF KINGSTON (OLD CITY)

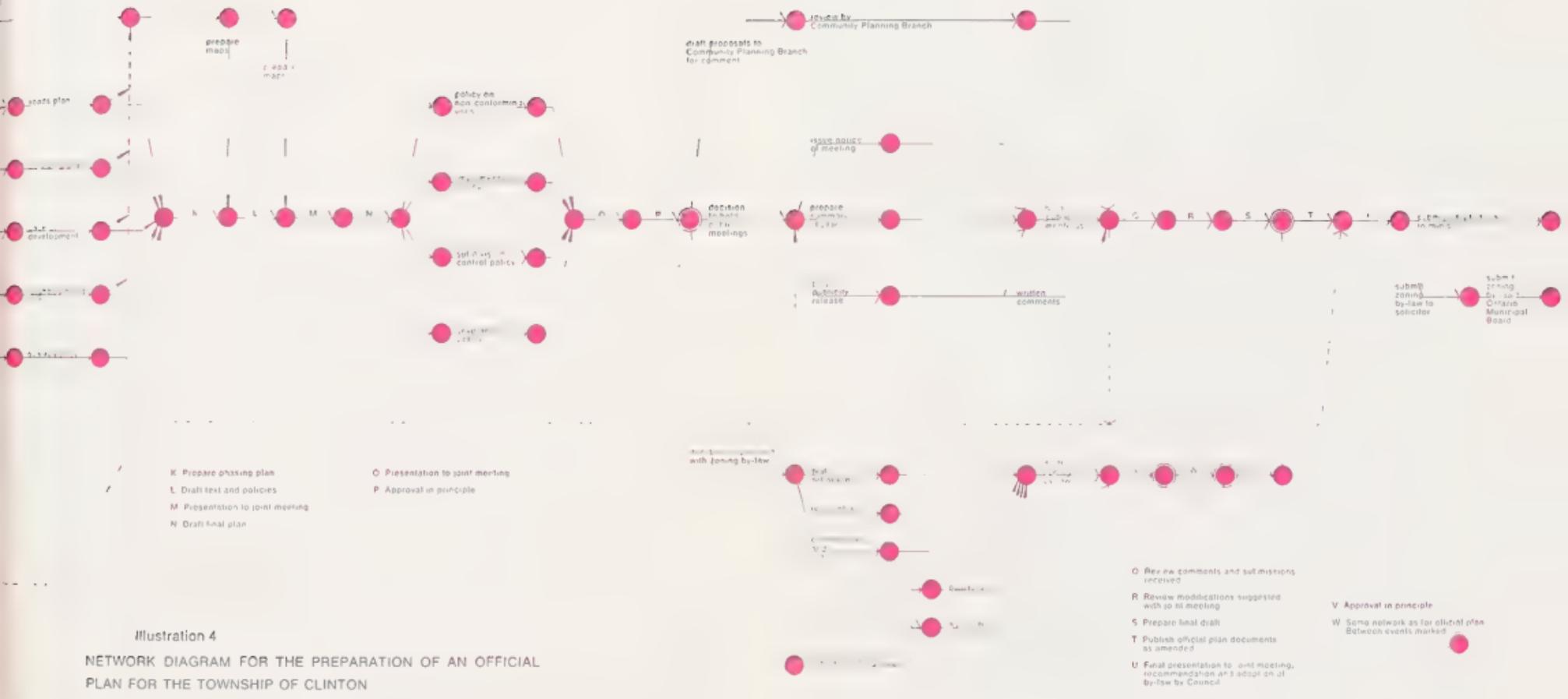
Source: Interview with Kurt Mumm, Planning Officer, Kingston

June, 1968

*4. Network Diagram for the Preparation of an Official Plan for the Township of Clinton* The preparation of an official plan for the Township of Clinton was preceded by an appraisal of the planning situation within the township. This appraisal, carried out for the council by a firm of consulting planners, resulted in a work program leading to the adoption of an official plan. The program closely parallels the hypothetical network diagram because prior to the decision to proceed with an official plan little or no background study had been undertaken. The preparation of a zoning by-law and other forms of control were also undertaken at an appropriate stage by the consultants. This program is included in the network illustration.

The Township of Clinton is rural in nature but does contain residential development in the areas surrounding two urban areas. The essential nature of the planning problems encountered involved control of quarrying activities along the Niagara Escarpment, the retention of prime agricultural land and the control of specific agricultural uses in relation to adjacent rural residential sites.





*5. Network Diagram for the Preparation of an Official Plan for the Central Ontario Joint Planning Area* Planning studies began in the Central Ontario Area in 1966. The first steps involved the preparation of a series of research reports on key aspects of the planning situation. Prior to the establishment of the joint board a number of studies of a local or area wide nature had been undertaken and these were used as inputs into the subsequent planning activities of the board.

Illustration 4.

NETWORK DIAGRAM FOR THE PREPARATION OF AN OFFICIAL  
PLAN FOR THE TOWNSHIP OF CLINTON

Source: Interview with Paul H. Pine and G. Cressman of J. M. Tomlinson and Associates Limited

June, 1968

In the Central Ontario Area a number of parallel activities are also involved, including a transportation study, a refuse disposal study and a study by the O.W.R.C.\* A decision has been made to proceed with the adoption of an "interim" official plan which can serve in the interval prior to the fruition of these large scale parallel studies.

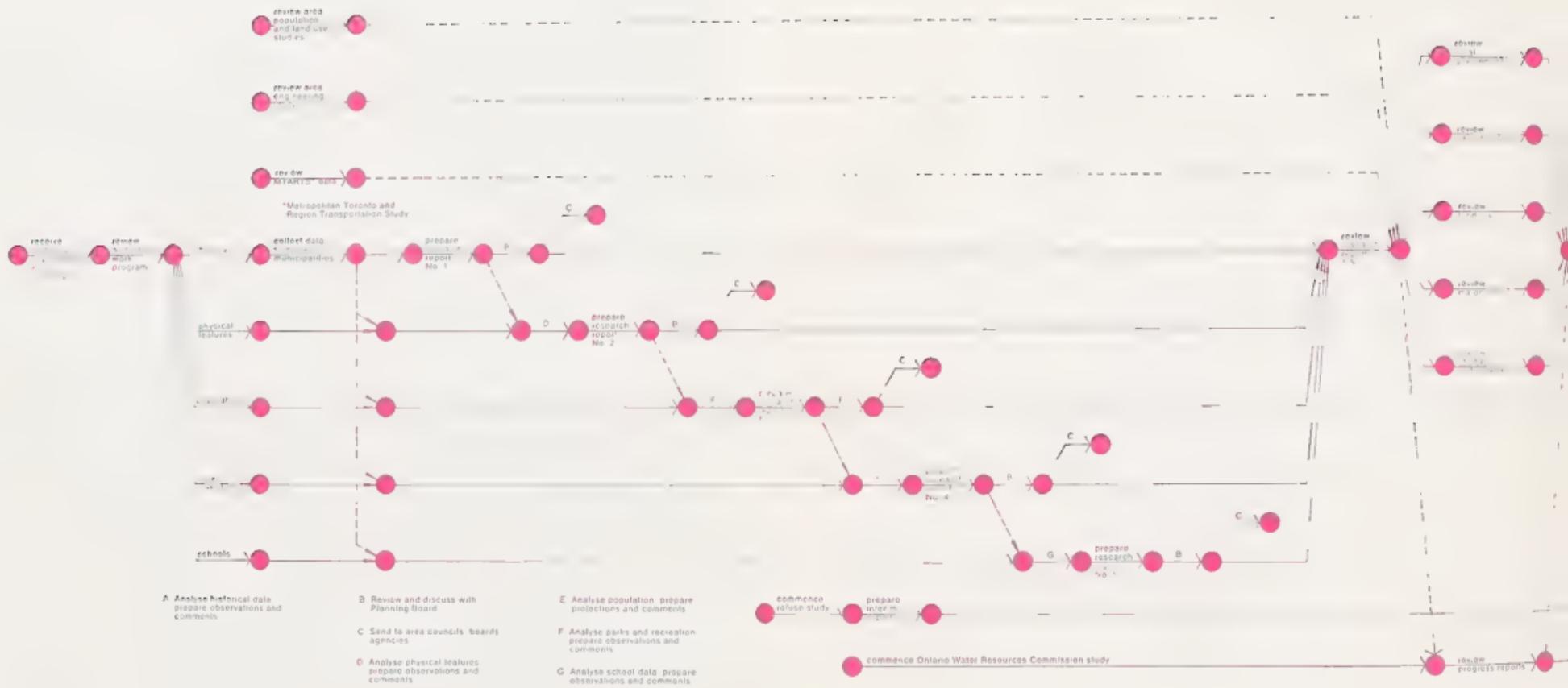
The network diagram presented in Illustration 5 shows these studies and the current status of the work program. The future program is also included for purposes of clarity. Obviously the program will not end with the diagram but will continue with the results of the transportation study and the O.W.R.C. study being fed into the stream when they are completed. It is contemplated that at that stage a revised official plan will be prepared, taking into account the newer information available to the planning board. A new official plan will then be adopted as a comprehensive amendment to the "interim" plan.

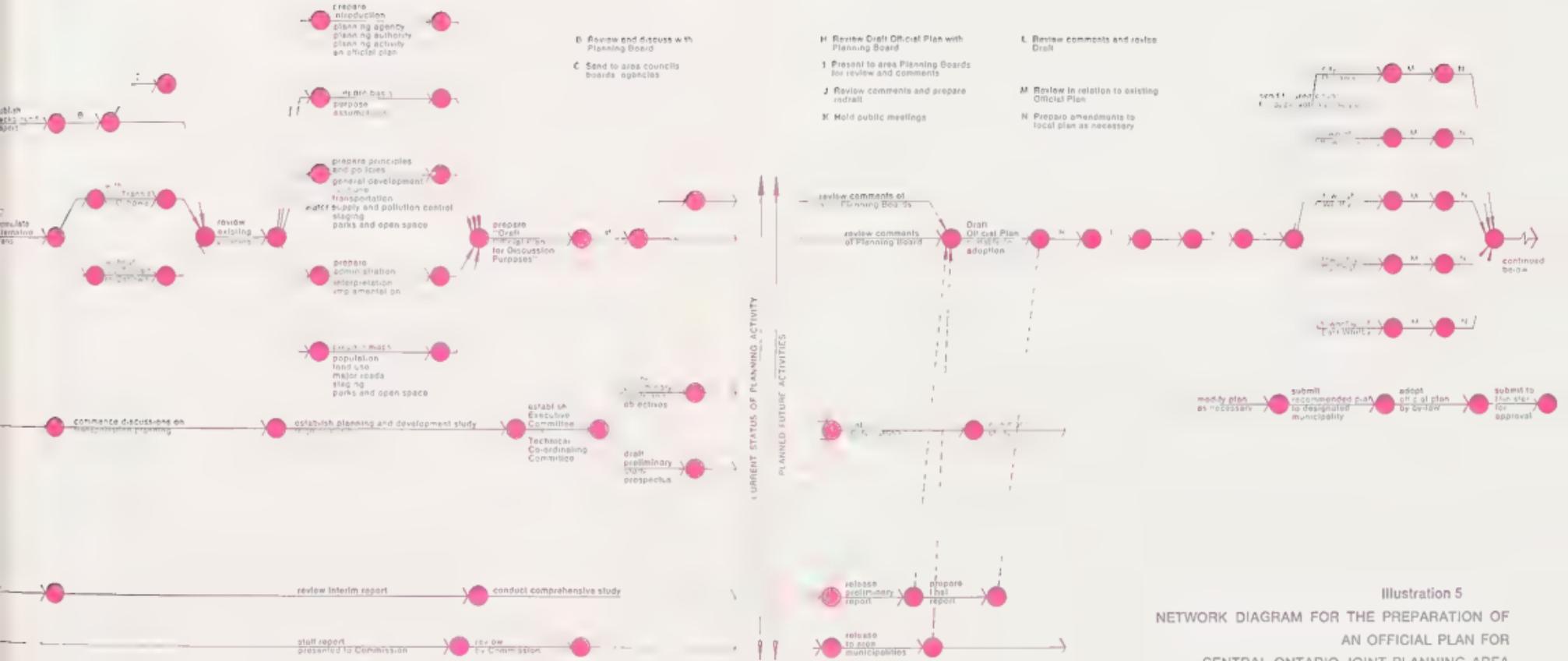
Illustration 5.

NETWORK DIAGRAM FOR THE PREPARATION OF AN OFFICIAL  
PLAN FOR CENTRAL ONTARIO JOINT PLANNING AREA

Source: Interview with William F. H. McAdams, Central Ontario Joint Planning Board  
June, 1968

\*Ontario Water Resources Commission





**Illustration 5**  
**NETWORK DIAGRAM FOR THE PREPARATION OF AN OFFICIAL PLAN FOR CENTRAL ONTARIO JOINT PLANNING AREA**

## **VI. FURTHER POSSIBILITIES FOR APPLICATION**

This manual has concerned itself with network diagramming for the preparation of official plans under The Planning Act in Ontario. It is apparent that other planning activities lend themselves to similar applications. Four illustrations of network diagrams for other planning activities in Ontario and elsewhere are provided below.

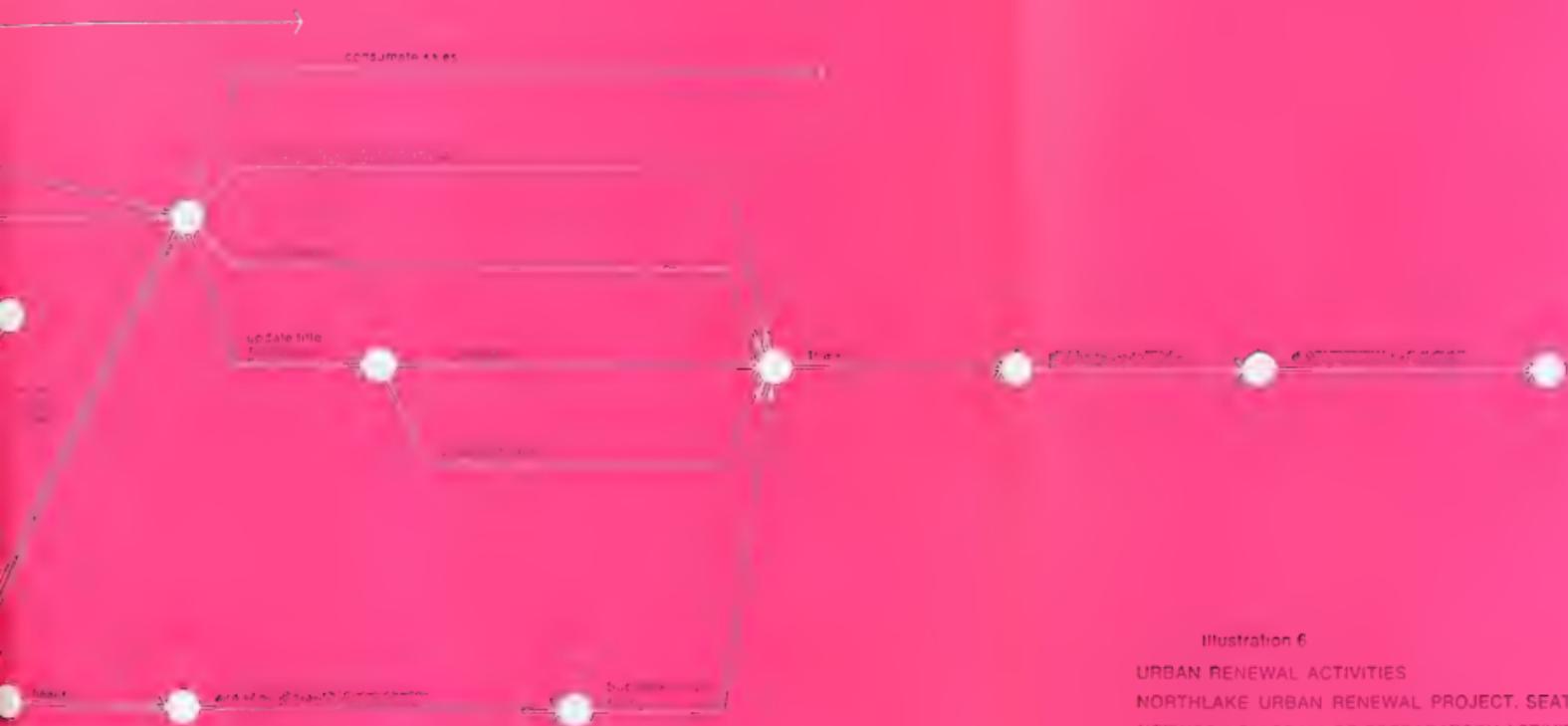


Illustration 6  
URBAN RENEWAL ACTIVITIES  
NORTHLAKE URBAN RENEWAL PROJECT, SEATTLE, WASHINGTON  
NETWORK DIAGRAM OF PREPARATORY ACTIVITIES

## 1 URBAN RENEWAL

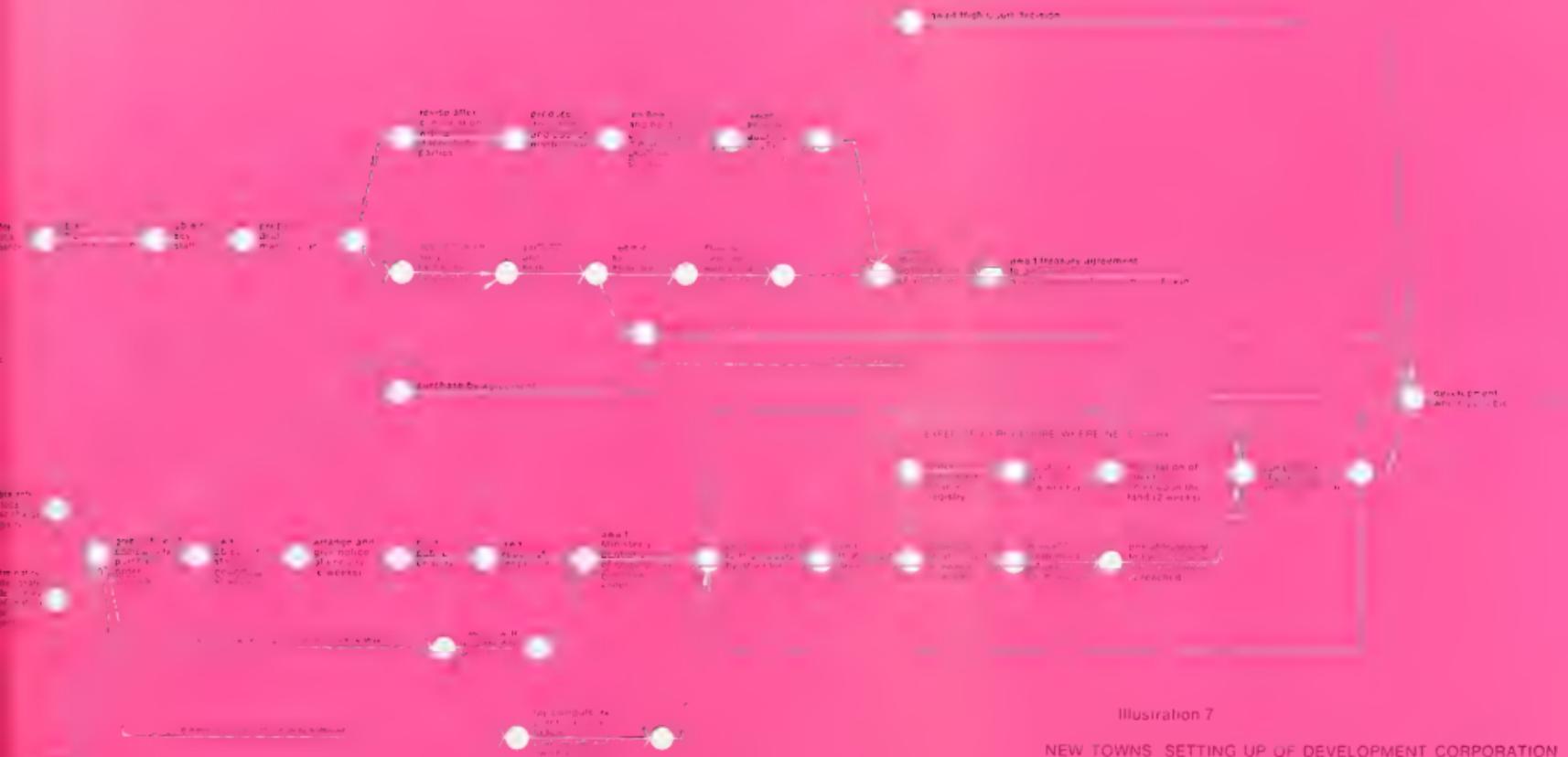
Urban renewal projects are complex and large-scale undertakings which require the proper scheduling and coordination of many skills at all levels of government and among many public and private agencies. The scale and intricacies of the task lend themselves to the use of PERT/CPM techniques. The illustration of the application of these methodologies to urban renewal has been adopted from Dueker, *Urban Renewal Scheduling by Critical Path Methods* (Illustration 6).

In the construction phases of urban renewal the use of CPM is well developed and illustrations of construction applications abound in the references.

Illustration 6  
URBAN RENEWAL ACTIVITIES  
NORTHLAKE URBAN RENEWAL PROJECT, SEATTLE, WASHINGTON  
NETWORK DIAGRAM OF PREPARATORY ACTIVITIES

Source: K. J. Dueker, *Urban Renewal Scheduling by Critical Path Methods*





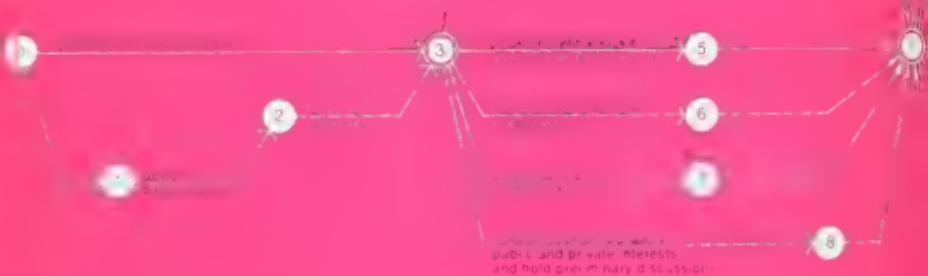
## 2 NEW TOWN PLANS

An illustration of network diagramming under the 1946 New Towns Act in the United Kingdom will be found in the Fine and Britten article, "Safety Nets for Urban Planners" taken from the *Journal of the Town Planning Institute* (Illustration 7). This network shows the way in which a development corporation may be set up for a new town and how it may acquire land subject to the requirements of the Act. While the network indicates only the precedence relationships and cannot be used for day-to-day control, it is useful for ensuring that all parties involved are aware of the overall process and of the implications of their phase of the work.

Illustration 7  
NEW TOWNS SETTING UP OF DEVELOPMENT CORPORATION  
AND LAND ACQUISITION

Source: "Safety Nets for Urban Planners," *Journal of the Town Planning Institute*, May 1966

Establish joint committee of local authority, planning authority, and developer for study and effect on organization of work



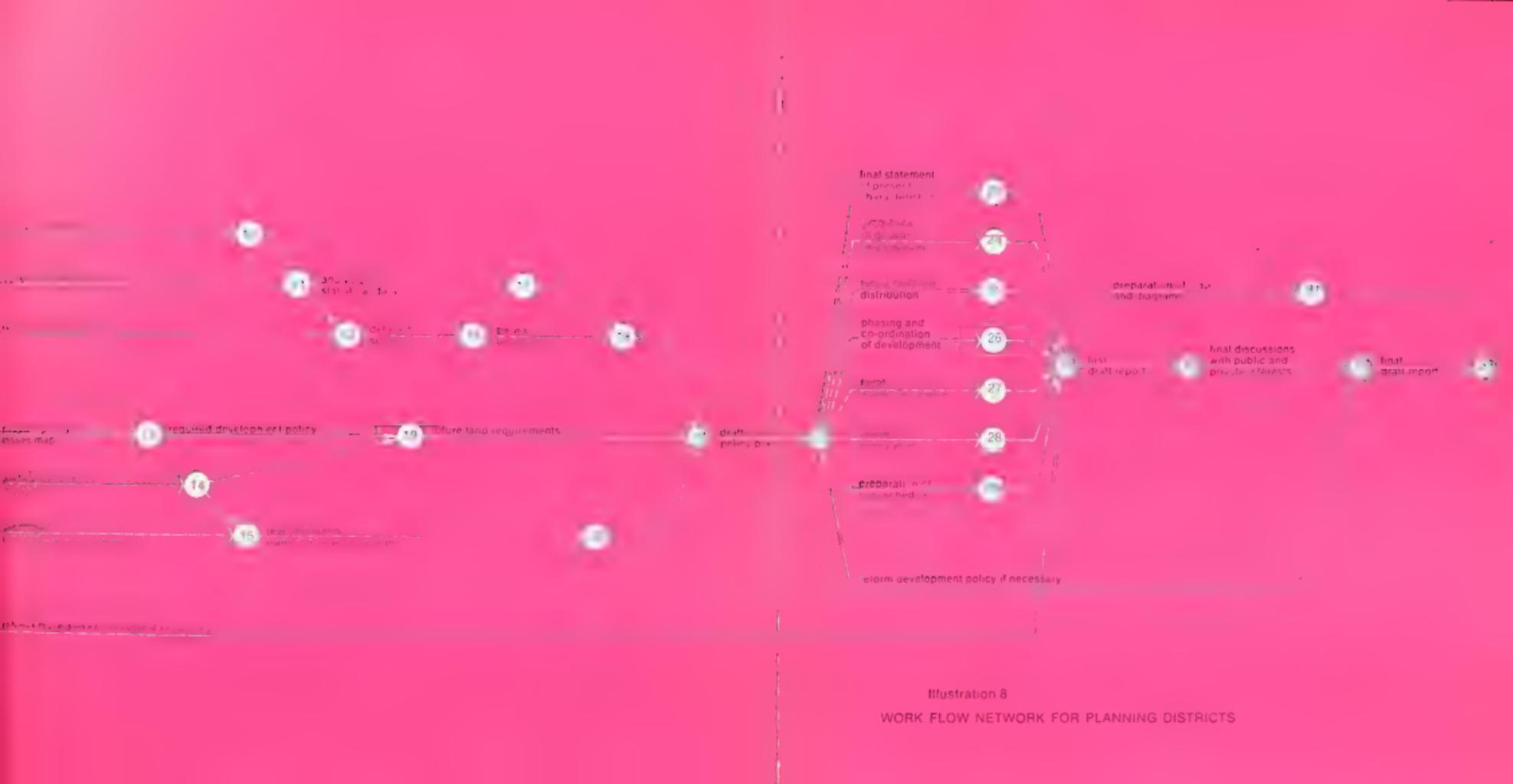


Illustration 8

WORK FLOW NETWORK FOR PLANNING DISTRICTS

### 3 DISTRICT PLANS

The work flow involved in the preparation of a district plan within the framework of a broad policy-type official plan has been diagrammed informally within the City of Toronto Planning Board (Illustration 8)

The purpose of the network is to illustrate the constraints imposed on the preparation of a detailed district plan by urban renewal activity, city-wide and metropolitan structure frameworks. It shows by a series of iterative loops how development concepts can be reformulated progressively as the planning process proceeds

Illustration 8  
WORK FLOW NETWORK FOR PLANNING DISTRICTS

Source: City of Toronto Planning Board, Long Range Division  
May 1967



**ILLUSTRATION 9**  
**DETAILED NETWORK DIAGRAMS**  
**PUBLICATION OF DOCUMENTS**

## APPENDIX A

### 4. DETAILED NETWORKS

More detailed network diagrams can be prepared to illuminate the inputs and work involved in report preparation, publication of documents, and the myriad of other details involved in planning work. Data gathering, analysis, drafting, computer programming, public meetings, preparation of static displays, progress reports and similar activities all bear on the completion of major projects.

The plotting of these activities may seem to be only an enlargement of the scope of network diagrams discussed previously. An understanding of each, and a critical evaluation of the procedures employed, may result in improved efficiency and the release of much needed resources which can be applied with advantage elsewhere in the program. The illustration is adopted from "Safety Nets for Urban Planners" (Illustration 9).

Illustration 9.  
**DETAILED NETWORK DIAGRAMS**  
**PUBLICATION OF DOCUMENTS**

Source: "Safety Nets for Urban Planners" *Journal of the Town Planning Institute*  
 May, 1966

### GLOSSARY OF PERT/CPM TERMINOLOGY

**Activity :** An element of a program which is represented on a network by an arrow. It may represent a process, a task, procurement cycle, waiting time, or simply a connection or an interdependency between two events in the network. Also called a "job" in CPM notation.

**Constraint :** The relationship of an event to a succeeding activity, implying an activity may not start until the event preceding has occurred. Also indicates the relationship of an activity to a succeeding event implying an event cannot occur until all activities preceding it have been completed.

**Critical Path :** The longest (time) path through the network. Several critical paths may be identified in a network and be ranked in order of their criticality.

**Duration (*te*) :** The elapsed time which an activity is predicted to require. In CPM it comprises a single-time estimate for the work to be accomplished stated in days, weeks or months. Sometimes referred to as "Expected Elapsed Time".

**Early Start** This is the earliest possible time an activity can start if the sequence of activities is to be preserved. The time is relative to the starting time of the whole project.

**Early Finish** This is the earliest time an activity can be completed. It is the sum of the early start time and the duration of the activity.

**End Event :** The event which signifies the completion of a network.

**Event** : A specific definable accomplishment in a program plan recognizable at a particular instant in time. Events do not consume time or resources and are normally represented in the network by a circle. Also called a "node" in CPM notation. Successor events immediately follow one another without intervening events. Predecessor events come immediately before an event without intervening events.

**Expected Date** : The calendar date on which an event can be expected to occur. It is calculated from the sum of the duration times along the longest path through the network to the given event.

**Free Slack** : This is the amount a job can be delayed without delaying the start of any other job.

**Interface Event** : An event which signals the necessary transfer of responsibility, end items, or information from one detailed network to another. For example, the receipt of a sewer plan from engineering, traffic counts from traffic engineering, or the release of a preliminary draft plan to the Superintendent of Schools for comment.

**Late Finish** : The latest date on which an activity can be completed without creating an expected delay in the completion of a project.

**Late Start** : The latest calendar date on which an activity can be started without delaying the completion of the program or project.

**Milestone** : The equivalent of an event.

**Network** : A flow diagram consisting of the activities and events which must be accomplished to reach the program objectives, showing their planned sequences of accomplishment, interdependencies and interrelationships.

**Program Breakdown Structure** : A family-tree subdivision of a program, beginning with the end objectives and then subdividing these objectives into successively smaller "End Item Subdivisions". It establishes the framework for defining the tasks to be accomplished, constructing a network plan, summarizing the schedule status of a program for progressively higher levels of supervision.

*Scheduling* : Determination and assignment of scheduled time to events and activities as distinct from duration times resulting from the initial network planning process.

*Scheduled Completion Date* : The date assigned for the completion of an activity or the occurrence of an event for purposes of planning and control within an organization during the scheduling process.

*Scheduled Duration (Ts)*: The period of time finally assigned for performing an activity during the scheduling process.

*Total Slack* : Total slack (or float) is the difference between the time allowed for an activity and its estimated duration time. It is calculated as: (LATE FINISH – EARLY START) – DURATION.

*Zero-Time Activity* : An activity which constrains the beginning of a following activity or occurrence of the event to which it leads by requiring that the event from which it proceeds occur first. Also referred to as a “dummy” activity.

## APPENDIX B

### PERT-CPM CONTRASTED

Beyond the differences in the environments in which PERT and CPM were developed and applied (as illustrated in Figure 4), they differ in a number of other ways. These tables give a brief summary of some of the differences.

#### CPM

Usually applied to well defined projects in which time factors are known with some degree of accuracy.

One dominant organization controls the end deliverable objective.

Uncertainties small.

Each project occurs at given location.

#### PERT

Usually applied to massive, poorly defined programs in which time factors can only be assigned within limits of probability.

Multiple organization in which many bodies contribute to the end product.

Uncertainties great.

Activities geographically dispersed.

There are also differences in the notation used.

**CPM**

Arrow Diagram	
Node	
Job	
Total Float	
Free Float	
Early Start Time	
Late Start Time	
Dummy Job	
Duration —	
a Single Time Estimate	
$te = m$	
where:	
$m = \text{estimated time}$	

**PERT**

Network	
Event (Milestone)	
Activity	
Primary Slack	
Secondary Slack	
Expected Date	
Latest Allowable Date	
Zero Time Activity	
Expected Elapsed Time —	
a Three Time Estimate	
$te = \frac{a + 4m + b}{6}$	

Where:

$a$  = optimistic estimate

$m$  = most likely estimate

$b$  = pessimistic estimate

$$\sigma^2 = \frac{(b - a)^2}{(6)}$$

= variance (the degree of uncertainty associated with the time for completion of the activity).

There are many other differences between CPM and PERT some of which concern the computer programming for each. References to these differences may be found in the texts listed in Appendix C. The Moder and Phillips text includes a complete chapter on this topic.

## APPENDIX C

### ANNOTATED BIBLIOGRAPHY

During the course of this study a number of sources were consulted. This bibliography represents a selection of the books, pamphlets and articles which should be readily found in libraries.

R. D. Archibald and R. L. Villoria, *Network-Based Management Systems (PERT/CPM)*, New York : John Wiley, 1967.

A comprehensive teaching text for university students on PERT/CPM. Covers the subject in 17 lecture/seminar sessions.

A. Battersby, *Network Analysis*, London : Macmillan, 1964.

A good standard reference for desk use by planners.

C. Clark, "The Optimum Allocation of Resources Among Activities of a Network", *Journal of Industrial Engineering*, January-February 1961, pp. 11-17.

An early published paper on the method by one of its developers. See also Kelley and Malcolm et. al. citations.

Roger L. Creighton, *PERTING a Transportation Study*, A paper presented to the 42nd Annual Meeting of the Highway Research Board, January 7-11, 1963.

An excellent paper with "real-life" examples of the application of PERT to a transportation study. Useful to planners because transportation studies are closely related to land-use studies and the illustrations involve the preparation of land-use forecasts and reports.

D. T. DeCoster, "PERT/Cost — The Challenge", In P. A. Firman and H. R. Anton, eds. *Contemporary Issues in Cost Accounting*, Boston : Houghton Mifflin, 1966, pp. 369-380.

Outlines the means of obtaining the optimum mix of time and cost on a project. Requires a basic understanding of the concepts of PERT/Time.

K. J. Dueker, *Urban Renewal Scheduling by Critical Path Methods*, unpublished Master's Thesis, University of Washington, 1963.

Provides a basis for utilization of the critical path techniques for planning and scheduling the execution of urban renewal projects. Includes a critique of both PERT and CPM.

H. F. Evarts, *Introduction to PERT*, Boston : Allyn and Bacon, 1964. A slim volume written for students in Business Administration. It aims at a basic understanding of PERT techniques, their nature, uses, strengths and weaknesses. Clear illustrations.

Federal Electric Corporation, *A Programmed Introduction to PERT*, New York : John Wiley, 1963.

A concise introduction to PERT using a form of programmed learning. Easy to follow with frequent repetition of the points being made. Extensive direction on the math involved.

B. Fine and J. R. Britten, "Safety Nets for Urban Planners", *Journal of the Town Planning Institute*, May 1966.

Presents typical applications of network analysis to organizing and coordinating urban planning activities. Hierarchies of responsibility are represented by diagrams of increasing detail. Includes 9 clear network diagrams of planning applications in the U.K.

J. Horowitz, *Critical Path Scheduling*, New York : Ronald Press, 1967. A standard textbook on PERT/CPM.

W. Katernityczuk, *Introduction to the Critical Path Technique : Theory Resumé*, Electronic Computing Branch, Ontario Department of Highways, 1966.

An instructional manual used to introduce staffs to the techniques of critical path method of analyzing complex programs. Can be a useful guide to standardizing terminology, symbols and computer outputs for all sections of the Provincial Government.

J. Kelley, "Critical Path Planning and Scheduling : Mathematical Basis", *Operations Research*, May-June 1961, pp. 296-321.

Another seminal article in PERT/Time. See also Clark and Malcolm et. al. citations.

R. L. Levin and C. Kirkpatrick, *Planning and Control with PERT/CPM*, New York : McGraw-Hill, 1966.

A comprehensive presentation of PERT/CPM with a chapter devoted specifically to CPM and how it differs from PERT. Also lists and describes 30 other methods of project planning and control.

F. K. Levy, et. al., "The ABC's of the Critical Path Method", in P. A. Firman and H. R. Anton, eds., *Contemporary Issues in Cost Accounting*, Boston : Houghton Mifflin, 1966, pp. 352-368.

Discusses an application of CPM to the construction industry. A rigorous and clear outline of how to determine the critical path and the advantages of analyzing, planning and scheduling complex projects.

D. G. Malcolm, et. al., "Applications of a Technique for Research and Development Program Evaluation", *Operations Research*, September-October 1959, pp. 646-670.

The earliest published article on PERT. See also Clark and Kelley citations.

R. L. Martino, *Project Management and Control* (3 volumes), New York : American Management Association, 1964.

An excellent presentation by a widely published author in the field of PERT/CPM. Assumes that the reader is not familiar with the subject. Volume I covers the basic ideas of PERT/CPM. Volume II concerns itself with using the critical path to produce an optimum program plan. Volume III outlines how to go about allocating and scheduling resources.

J. J. Moder and C. R. Phillips, *Project Management with CPM and PERT*, New York : Reinhold, 1964.

A clear treatment of the subject with precise steps outlined from project planning, time estimation, and level of detail through to project control. Includes rules, pitfalls and computer applications as appendices.

W. Miller, *Schedule, Cost, and Profit Control with PERT*, New York : McGraw-Hill, 1963.

Provides a concise historical background to the development of PERT/Time and PERT/Cost. Outlines the fundamentals of the network technique. Clarifies the disparate terminology used by PERT and CPM and the ground rules for handling activities and events on a network, critical path evaluation and replanning. A glossary of terms and a comprehensive bibliography up to 1963.

City of Pittsburgh, *Introduction to Network Planning*, Pittsburgh : Department of City Planning, May 1963.

A manual designed to acquaint the staff of the Pittsburgh City Planning Department with the concepts of PERT and CPM. A clear and well illustrated outline of the origins of PERT/CPM, definitions of terms, program planning, and the methods of network planning.

## BIBLIOGRAPHIES

Council of Planning Librarians, *PERT and CPM : A Selected Bibliography*, Exchange Bibliography No. 53, P.O. Box 229, Monticello, Illinois, (61856), Council of Planning Librarians, June 1968.

A comprehensive bibliography of references to PERT/CPM. Contains a section on planning and transportation. Few references of direct relation to planning not already cited above.



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